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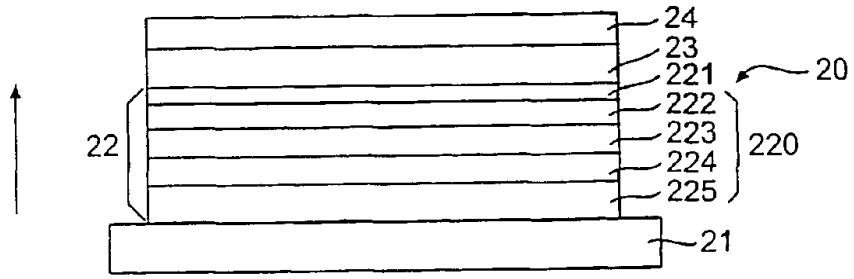

(57) Abstract

The present invention is direct to the concept of an electrode for an OLED (20) formed from multiple layers of metal and dielectric materials that can be ordered to produce a highly efficient electrode (22). The layers of the electrode (22) may be stacked such that different portions of the electrode fulfill the separate functionalities of high electrical conductivity, high electrical injection and high optical transmission/reflection.

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ORGANIC ELECTROLUMINESCENCE DEVICE WITH HIGH EFFICIENCY REFLECTING ELEMENT

CROSS REFERENCE TO RELATED PATENT APPLICATION

This application relates to and claims priority on provisional application serial number 60/131,475, filed April 28, 1999.

FIELD OF INVENTION

The present invention relates to an organic electroluminescence device. In particular, the present invention relates to a layered or stacked electrode for an organic electroluminescence.

BACKGROUND OF THE INVENTION

An organic electroluminescence device or organic light emitting device ("OLED") is a stack of organic thin films which are in physical contact between two electrodes. The basic structure of an OLED **1** is illustrated in Fig. 1. The OLED **1** includes a substrate **10**, a first electrode **11** formed on the substrate **10**, at least one organic thin film layer **12** formed on the first electrode **11**, and a second electrode **13** formed on the at least one organic thin film layer **12**. Typically, several organic thin film layers are sandwiched between the electrodes **11** and **13**. The electrodes **11** and **13** may be optically reflective or transmissive, depending on the desired direction of light exiting from the OLED **1**. The OLED **1** may be encapsulated to maintain material and structural integrity.

The first electrode **11** may be formed from indium tin oxide ("ITO") which has high optical transmission, electrical conductivity and high electrical injection into the at least one organic thin film layer **12**. An electrode formed from ITO can be made to have 80-90% optical transmission with 10-100% sheet resistances. ITO is also an operationally good positive-carrier for electrical injection into the at least one organic thin film layer **12**. When the first electrode **11** is formed from ITO on substrate **10**, the OLED **1** is known as a "down emitting" because the optical output passes through the substrate **10** to the viewer. The second electrode **13** is then formed from a partially reflective material (e.g., molybdenum, ruthenium and vanadium). The second electrode **13** has a thickness of approximately 1000Å.

In a "down emitting" OLED, the second electrode **13** may be formed from a pair of layers **131** and **132**, as shown in Fig. 2. A very thin layer **131** of a dielectric material (e.g., LiF and SiO_2) is formed on the at least one thin film layer **12**. The layer **131** has a thickness of less than 100Å. A thicker layer **132** of aluminum is formed on the thin layer **131**. The thicker layer **132** of aluminum has an approximate thickness of 2000Å. Although the operation of composite electrode having layers **131** and **132** is not fully understood, the thin layer **131** is thought to assist electron injection into select organic materials of the thin film layer **12**. The aluminum layer **132** is believed to provide functional conductivity and reflectivity within the context of a "down emitting" OLED.

OBJECTS OF THE INVENTION

It is an object of the present invention to increase the optical output efficiency of an organic electroluminescence device.

It is another object of the present invention to provide an OLED having an electrode having high optical transmission.

It is another object of the present invention to provide an OLED having an electrode having high optical reflection.

It is another object of the present invention to provide an OLED having an electrode having high electrical conductivity.

It is another object of the present invention to provide an OLED having a low-loss, highly directional and reflective element as an integral part of a composite electrode element.

It is another object of the present invention to provide an OLED having a low-loss, highly directional and reflective element as an integral part of a composite electrode element that contacts the organic stack of the OLED.

It is another object of the present invention to provide an OLED having omnidirectional reflectors as part of an electrode element to boost performance of the OLED.

It is another object of the present invention to provide an OLED having omnidirectional reflectors as part of an electrode element to boost performance of the OLED by promoting greater optical output through the reduction of optical losses.

It is another object of the present invention to provide an OLED having omnidirectional reflectors as part of an electrode element to boost performance of the OLED by promoting greater directionality of the output optical beam.

It is another object of the present invention to provide an OLED having an electrode comprising a layered stack of metallic and/or dielectric materials.

It is another object of the present invention to provide an OLED having an electrode comprising a layered stack of metallic and/or dielectric materials, which separately functionalize the requirements of high optical transmission or reflection, high electrical conductivity, and high electrical injection into the organic stack.

SUMMARY OF THE INVENTION

The present invention is directed to the concept of an electrode for an OLED formed from multiple layers of metal and dielectric materials that can be ordered to produce a highly efficient electrode. The layers of the electrode may be stacked such that different portions of the electrode fulfill the separate functionalities of (1) high electrical conductivity, (2) high electrical injection and (3) high optical transmission/reflection.

The present invention is directed to an OLED having a substrate, a first electrode formed on said substrate, at least one organic thin film layer formed on the first electrode, and a second electrode formed on the at least one organic thin film layer. In accordance with the present invention, at least one of the first and second electrodes includes a plurality of electrode layers. The plurality of electrode layers includes a thin film layer formed at least one of a metal and an oxide, and a multilayer reflector. The thin film layer preferably has a thickness of less than 100Å.

The multilayer reflector includes a plurality of layers. The plurality of layers may include at least one metal layer and at least one dielectric material layer. The plurality of layers preferably includes alternating layers of the at least one metal layer and the at least one dielectric material layer.

In accordance with one embodiment of the present invention, the first electrode includes the plurality of electrode layers. In accordance with another embodiment of the present invention, the second electrode includes the plurality of electrode layers.

The plurality of electrode layers preferably includes at least one layer formed from a high electrical conductivity material. The plurality of electrode layers preferably includes at least one layer formed from a high electrical injection material. The plurality of electrode layers preferably includes at least one layer formed from a material having a high optical transmission. The plurality of electrode layers preferably includes at least one layer formed from a material having a high optical reflection.

The present invention is also directed to an electrode for an OLED, the electrode includes a plurality of electrode layers, wherein the plurality of electrode layers includes a thin film layer formed at least one of a metal and an oxide, and a multilayer reflector. The thin film layer has a thickness of less than 100Å. The multilayer reflector includes a plurality of layers. The plurality of layers includes at least one metal layer and at least one dielectric material layer. The plurality of layers preferably includes alternating layers of the at least one metal layer and the at least one dielectric material layer.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in conjunction with the following drawings in which like reference numerals designate like elements and wherein:

Fig. 1 is a schematic view of a conventional OLED;

Fig. 2 is a schematic view of another conventional OLED;

Fig. 3 is a schematic view of an upwardly emitting OLED according to an embodiment of the present invention; and

Fig. 4 is a schematic view of a downwardly emitting OLED according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to a preferred embodiment of the present invention, an example of which is illustrated in the accompanying drawings. The OLED **20**

in accordance with one embodiment of the present invention is illustrated in Fig. 3. The OLED **20** includes a substrate **21**. A first electrode **22** is formed on the substrate **21**. At least one organic thin film layer **23** is formed on the first electrode **22**. A second electrode **24** is formed on the at least one organic thin film layer **23**. The OLED **20** is an upwardly emitting OLED. In an upwardly emitting OLED, light is transmitted through the second electrode **24**. The substrate **21** is formed from an opaque material (e.g., silicon). The second electrode **24** is formed from a suitable light transmissive material to permit output of the OLED to exit away from the substrate **21** in the direction of the arrows illustrated in Fig. 3.

The first electrode **22** is formed from a plurality of layers. A thin film layer **221** is in direct contact with the at least one organic thin film layer **23**. The layer **221** has a thickness of less than 100Å. The layer **221** is formed from a material that promotes positive carrier injection into the at least one organic thin film layer **23**. The layer **221** is preferably formed from a metal or an oxide. Suitable metals include molybdenum, ruthenium and vanadium. The present invention, however, is not limited to these materials, rather metals exhibiting similar physical properties are considered to be well within the scope of the present invention. The layer **221** may be formed from oxides of molybdenum, ruthenium, and vanadium or other suitable metals. ITO, aluminum-zinc oxide and mixtures thereof are suitable materials for layer **221**.

Positioned between the substrate **21** and the thin layer **221** are alternating layers of metals and dielectric materials **222**, **223**, **224**, **225** forming a high-performance, multilayer reflector **220**. This reflector layer **220** has ideal reflectivities, omnidirectionality and low loss, in what is known as a "dielectric omnidirectional reflector." This composite reflector is tuned to the wavelength of electroluminescence emission by suitable choices of the alternating metal and dielectric materials. The omnidirectional mirror combines the best properties of each by inhibiting energy losses through optical interference effects in the periodic, alternating structure.

A second embodiment of the present invention depicted a "downwardly emitting" OLED **30** is illustrated in Fig. 4 having a substrate **31**. In a "down-emitting" application, the

first electrode **32** is of the usual type, e.g., ITO, and the second electrode **34** is reflective. A thin layer **341** is positioned adjacent to the at least one organic layer **33**. The layer **341** is a thin, transparent negative-carrier injector having a thickness of less than 100Å. The layer **341** is preferably formed from codeposited layer of magnesium and silver.

A plurality of alternating layer **342**, **343**, **344** and **345** forming a high-performance, multilayer reflector **340** are formed on thin layer **341**. The multilayer reflector **340** may also serve as a protective layer for the thin metallic injector **341**.

While this invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. An organic light emitting device comprising:

a substrate;

a first electrode formed on said substrate;

at least one organic thin film layer formed on said first electrode; and

a second electrode formed on said at least one organic thin film layer, wherein at least one of said first and second electrodes includes a plurality of electrode layers.

2. The organic light emitting device according to Claim 1, wherein said plurality of electrode layers comprises:

a thin film layer formed of at least one of a metal and an oxide; and

a multilayer reflector.

3. The organic light emitting device according to Claim 2, wherein said thin film layer has a thickness of less than 100Å.

4. The organic light emitting device according to Claim 2, wherein said multilayer reflector includes a plurality of layers.

5. The organic light emitting device according to Claim 4, wherein said plurality of layers includes at least one metal layer and at least one dielectric material layer.

6. The organic light emitting device according to Claim 5, wherein said plurality of layers includes alternating layers of said at least one metal layer and said at least one dielectric material layer.

7. The organic light emitting device according to Claim 2, wherein said first electrode includes said plurality of electrode layers.

8. The organic light emitting device according to Claim 2, wherein said second electrode includes said plurality of electrode layers.

9. The organic light emitting device according to Claim 1, wherein said plurality of electrode layers includes at least one layer formed from a high electrical conductivity material.

10. The organic light emitting device according to Claim 1, wherein said plurality of electrode layers includes at least one layer formed from a high electrical injection material.

11. The organic light emitting device according to Claim 1, wherein said plurality of electrode layers includes at least one layer formed from a material having a high optical transmission.

12. The organic light emitting device according to Claim 1, wherein said plurality of electrode layers includes at least one layer formed from a material having a high optical reflection.

13. An electrode for an organic light emitting device, said electrode comprising:

a plurality of electrode layers, wherein said plurality of electrode layers includes a thin film layer formed at least one of a metal and an oxide, and a multilayer reflector.

14. The electrode according to Claim 13, wherein said thin film layer has a thickness of less than 100Å.

15. The electrode according to Claim 13, wherein said multilayer reflector includes a plurality of layers.

16. The electrode according to Claim 15, wherein said plurality of layers includes at least one metal layer and at least one dielectric material layer.

17. The electrode according to Claim 16, wherein said plurality of layers includes alternating layers of said at least one metal layer and said at least one dielectric material layer.

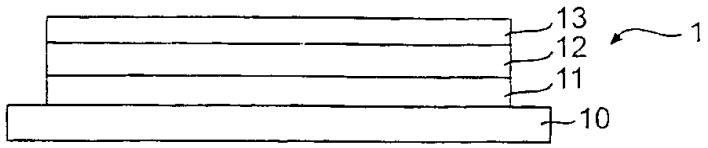

FIG. 1

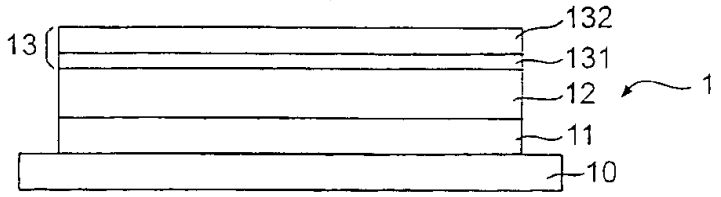

FIG. 2

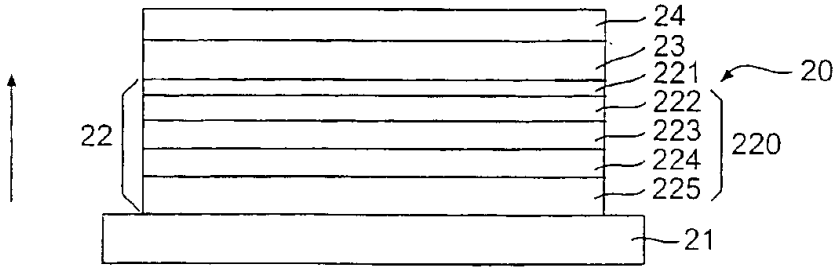

FIG. 3

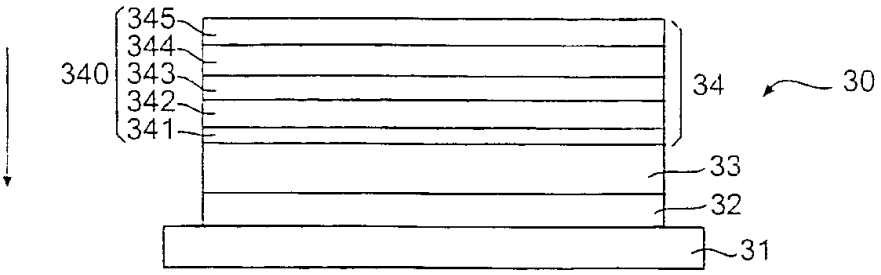

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/11161

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H05B 33/00, 33/12

US CL :313/504, 428/690

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/690; 313/498, 499, 500, 501, 502, 503, 504, 505, 506; 315/169.3; 445/35, 46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,814,416 A (DODABALAPUR et al) 29 September 1998 (29-09-1998), col. 3, line 54-col. 5, line 6.	1-17
Y	US 5,811,833 A (THOMPSON) 22 September 1998 (22-09-1998), col. 10, line 26-col 11, line 25.	1-17
Y	US 5,674,636 A (DODABALAPUR et al) 07 October 1997 (07-10-1997), entire document.	1-17
Y	US 5,635,307 A (TAKEUCHI et al) 03 June 1997 (03-06-1997), entire document.	1-17
Y	US 5,405,710 A (DODABALAPUR et al) 11 April 1995 (11-04-1995), entire document.	1-17

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